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DAIRY WASTE TREATMENT BY AERATION

by R. Rupert Kountz* and Nandor Porges**

INTRODUCTION

Dairy waste water is a nuisance in every dairy plant. Management must get rid of this waste water either directly or after its treatment. Direct disposal of waste water - its removal from the property without any treatment - is achieved most simply by means of a public sewer system. The use of sewers relieves management of any responsibility for operating a treatment system, but requires excellent housekeeping to keep the sewage service charge as low as possible. Direct disposal of waste water is also possible by sub-surface tile field, by spray irrigation, or by other applicable methods, but such disposal places on management some degree of responsibility for operating and maintaining the system. In spite of this, these systems are lower in cost and simpler to operate than a treatment plant.

Waste treatment is essential if waste-disposal facilities are not available. Treatment of any dairy waste water is technically feasible. It is generally more expensive than disposal and places a high degree of responsibility on management. The construction cost and the operating cost will vary with good housekeeping and water economy in the dairy.

Research on treatment of dairy waste has been underway at the Eastern Regional Research Laboratory since 1948 following the suggestion of the Subcommittee on Dairy Waste of the Dairy Industry Committee. Results have been published as phases of the study have been completed. These laboratory investigations were supplemented by a 3-year pilot-plant study at the Pennsylvania State University. Results, ideas, and concepts obtained in the laboratory have been verified in the pilot plant and adapted to industrial practice.

The object of this report is to present in a concise, simple and complete manner information on the treatment of dairy waste as derived from the above studies. For more specific detail, reference is made to the appended list of publications, which have been selected from a total of about 40 that have been published since this work was undertaken. It is anticipated that complete information on a 10,000-gallon pilot-plant study that was recently completed at the Pennsylvania State University will be available in a forthcoming University Engineering Bulletin.

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The continued interest of the Dairy Industry Committee through its Subcommittee on Dairy Waste Disposal is acknowledged and deeply appreciated. Its suggestions and advice given at many conferences and interviews have been of great value toward arriving at an economical and efficient method of treating dairy waste.

WASTE CHARACTERISTICS

Dairy waste water is the liquid discharge from a dairy plant, and contains primarily milk solids which adhered to the equipment and were removed by washing. In addition to this source of lost milk solids, there are also leaks, spills, and the disposal of byproducts (whey), and discarded items.

The lost milk solids are dispersed in the cleaning water, whose daily volume is dependent on the housekeeping practices in the dairy, as well as on the cost of the water. In the older dairies, the cooling water and evaporator water may be in the same sewer with the clean-up water. In this latter situation the waste will be quite dilute, and the size (and obviously the construction cost) of the treatment plant will be excessive.

Various standards for processing losses have been established, but probably the simplest expression is that of an equivalent percentage loss based on the daily weight of milk received. This value will vary from 1% loss for receiving stations to as much as 3% loss for small market milk dairies. While lower values are possible with rigid supervision, the general operating conditions will fall within these limits.

Water usage is harder to evaluate than are milk losses, but its weight will generally be equal to or greater than that of the milk received. Surveys have shown the extremes to vary between 100 and 200 gallons of water used for each 1,000 lb of milk received, neglecting cooling water and non-pollutional wastes.

RELATION OF TREATMENT COST TO VOLUME AND STRENGTH OF WASTE

Essentially, the volume of waste per day will influence the cost of construction of the treatment plant, whereas the strength of the waste will manifest itself in the cost of operation as well as the cost of construction. Thus, if water economy and good housekeeping are ignored, an abnormally high annual cost for the installation will result.

The size of the treatment units in a plant will depend not only upon the total volume of the waste water produced per day, but also upon the length of operating period of the dairy, and upon the intensity of peak water usage as well as the milk wasted by leaks, spills and willful wastes. The nature of dairy waste water is such that if it is stored improperly for appreciable lengths of time for flow equalization it may be detrimental to the treatment process.

Every biological treatment system requires a definite minimum weight of oxygen which must be made available to the system. Whether this weight of oxygen is supplied by means of a trickling filter or by a pumped aeration system makes little difference. Unless the essential amount of 0.65 lb of oxygen for each pound of milk solids in the waste water is furnished, the system will become anaerobic with all of the obnoxious odors characteristic of such a decomposing mixture. In actual projects it may be necessary for the engineering design to supply somewhat more than this theoretical minimum amount due to the general configuration of treatment systems. The point is, however, that in the initial construction, this oxygen supply condition must be met either by a large capital investment, as in construction of trickling filters, or by a large electrical power charge as required in the activated sludge process.

In preparing the engineering estimate for the annual charge of waste treatment, the operations within the dairy play a most important part. Housekeeping is of great importance, and the continual cooperation of employees should be enlisted to reduce the milk-solids loss to a reasonable value. While it is possible for the sanitary engineer to design a waste-treatment plant which can treat large quantities of skim milk, whey, and discarded products, it is doubtful if management can justify the total daily operating cost of such a system. It is far more economical to segregate these concentrated materials and provide separate disposal by drying, feeding or other means.

The cost of the treatment plant is much less than that of conventional sewage design of municipal plants since unessential units are omitted and equipment is kept to a minimum. Further, operation may be completely automatic.

BASIC THEORY OF THE TREATMENT PROCESS

In the effective treatment of dairy waste water, chemical processes are not of sufficient merit to justify their cost and, for that reason, the biological processes are in greater favor. Fortunately, the biological process is based upon the fact that a mixed aerobic culture exists in the treatment system and utilizes the milk solids in the waste water as a food supply for its own growth and propagation. These purifying organisms are microscopic in size and are almost the same density as the waste water. Hence means must be provided for their retention and also for allowing the purified waste water to leave the waste-treatment system.

It is possible for the purifying culture of a treatment system either to exist on the surface of a coarse stone bed or to exist in suspension in the liquid. The trickling filter purification system has a very high initial cost and a low operating cost, whereas just the reverse is true for the liquid-suspension type (activated sludge); from a tax write-off standpoint, the latter may be more economical and attractive to management.

In the purification process the flora cannot remove the milk solids from the waste water unless dissolved oxygen is available. The process is essentially one of wet combustion, and is almost identical in principle to the combustion of paper in a furnace. For complete oxidation, 1.25 lb of oxygen per pound of milk solids, plus the amount needed by the sludge cells, must be made available. For purification only, 0.50 lb of oxygen per pound of milk solids, plus 0.15 lb for the cell demand, is sufficient. The engineer must make a basic decision as to which of these conditions is to be met.

If only purification with the minimum amount of oxygen utilization is the objective, then separate provision must be made for removal of the excess sludge. On the other hand, if the total amount of oxygen is supplied in the plant design, separate external sludge digestion units are not necessary. But the system must be supplied with adequate oxygen throughout day and night in order to permit the continuous oxidation (that is, disposal) of the sludge.

The sludge remaining after purification of dairy waste is much higher in concentration (3,000-5,000 ppm) than that which is common to sewage-treatment processes (1,500 ppm). In view of this high concentration, units must be provided that will assist in the settling of the sludge, yield an effluent low in solids, and still accommodate the peak rates of flow in the dairy. Otherwise the system will become ineffective and will discharge undesirable quantities of sludge into the stream.

It is possible to operate the biological-oxidation process either as a continuous-flow type or as a fill-and-draw system. This decision will have no bearing on the biological process, but will depend entirely upon the dairy and its location as well as on the engineer's analysis of the local situation.

AERATION

Oxygen supply is the most essential engineering design consideration in the overall treatment process. A large variety of patented aeration devices are available for use by the engineer. These range from air outlet holes in manifold pipes to intricate mechanical and hydraulic devices. Unfortunately, these devices have been designed with regard to the volume of air flow rather than on the basis of their capacity to dissolve a known weight of oxygen in the liquor. Since the biological process of dairy waste treatment definitely depends upon the weight of dissolved oxygen available, the devices should be considered in terms of their efficiency in dissolving the oxygen in the air that is forced through them. Drilled holes have an efficiency of 2-3%, showing that only this small quantity is dissolved in the water from the total oxygen available in the air flow. The various porous diffusers are somewhat better, with an efficiency of approximately 5%. The hydraulic and hydraulic-mechanical devices have an oxygen transfer efficiency of 20-25%. It is of littl importance to the biological process which device is employed so long as the oxygen requirements are supplied, although it is claimed by some workers that exceptionally high liquid velocities cause foaming in the oxidation tank.

Obviously,any aeration system must not require a great deal of maintenance. Thus, if it were possible to dissolve enough oxygen by simply using an air pipe with many holes in it, such a unit would be preferable, in spite of its high power requirement, to a more efficient unit requiring frequent or almost continual maintenance attention.

In addition to the air supply furnishing the necessary oxygen, the air is also utilized to maintain complete suspension of the biological sludge culture. If the treatment process is not purifying the waste and is producing odors, then either the air supply must be increased until the process is aerobic, or the total weight of milk solids entering the treatment plant each day must be decreased by improved housekeeping.

After the minimum oxygen requirement of the milk waste and sludge culture has been satisfied, the use of excess air or oxygen will not accelerate the process since the rate of oxidation is a function of the liquid temperature.

PROCESS OPERATION

Fundamentally the process sequence of waste treatment involves only two units, the oxidation-purification tank and the sedimentation tank. In the case of a batch process, these two units may be combined, sedimentation occurring while the air supply is temporarily shut off.

The waste water should go directly to the oxidation tank without passing through any sedimentation chamber or surge tank in order to avoid putrefaction and its associated odors. After passing through a screening device, the waste should enter the oxidation tank in such a manner as to achieve the most complete intermixing. It is detained in this unit for 6 to 8 hours in order that the equilibrium concentration of activated sludge will not exceed 5,000 ppm. From this tank the waste can be discharged to the sedimentation tank, and from there to the outfall sewer. It is essential that the sludge in the sedimentation tank be returned continually to the oxidation tank in order to facilitate its own oxidation, or be removed from the system.

With the batch process, two hours sedimentation time will usually produce a satisfactory purification of the liquid contents by settling. Proper location and sizing of the outlet pipe will permit this color liquid to be decanted from the tank, after which the aeration must be resumed immediately in order to avoid odors and to oxidize the sludge cells.

It must be emphasized that dairy waste water is not domestic sewage, and that the engineering approach to the problem must be along the lines of biologically oxidizing milk solids, or along the lines of a fermentation process in which a dilute nutrient solution is aerated to yield cell solids and gases. It must be remembered that quantities of air and plant units considered satisfactory for conventional sewage treatment cannot necessarily be changed in an obvious direct proportion. Furthermore, sewage can be allowed to stand for a number of hours without any appreciable harm to its chemical contents and odor characteristics, whereas dairy waste will rapidly decompose, form acids, precipitate casein, and produce odors, all of which are undesirable in the treatment system. The use of simple air agitation in a sump or holding tank has little merit other than keeping the contents in suspension; because the oxygen cannot satisfy the requirements, the anaerobic process will occur rapidly. However, a properly aerated equalizing tank may be of value. The discharge of spent caustic solution from bottle washing will definitely destroy the biological flora in the system. This spent solution should be run to a leeching pit.

WASTE-TREATMENT PLANNING

In planning a waste-treatment system it is necessary to secure the services of a sanitary engineer familiar with the principles of biological oxidation of dairy waste as outlined in the last 8 years of research reports. Such a qualified engineer will design a plant on the basis of current laboratory techniques and information. If his design and advice are followed without deviation, the plant should operate properly from its first day of installation.

It will be necessary for the engineer to familiarize himself with the processes of the dairy and with its research and production figures for recent years. On the basis of these and the honest opinions of management, the engineer will attempt to design the treatment plant for the next five years of dairy operation. In the interests of economy, he will advise the segregation of unpolluted waters in the dairy.

Regardless of how well a waste-treatment system is designed and built it will not operate efficiently without the sincere cooperation of management.

Waste-treatment units, like any other piece of production equipment, have a maximum capacity. At present, units are in operation that treat the wastes from dairies with milk receipts of 12,500 to 250,000 lb or more daily. When the capacity of a treatment unit is reached, the engineer must advise as to necessary changes. Otherwise the processing of waste through the outgrown original system will be ineffectual and will create a nuisance with resulting poor public relations.

The operation of a dairy waste-treatment system requires the same careful attention as the making of buttermilk or some similar process within the dairy. If its operation and maintenance are neglected and abused, then the process becomes out of balance and its degree of perfection is impaired. It is based upon fundamental biological laws of nature which no man or equipment can alter. However, by intelligent engineering and proper attitude of management, these fundamental laws of nature can be utilized to provide an efficient and relatively trouble-free means of dairy-waste treatment.

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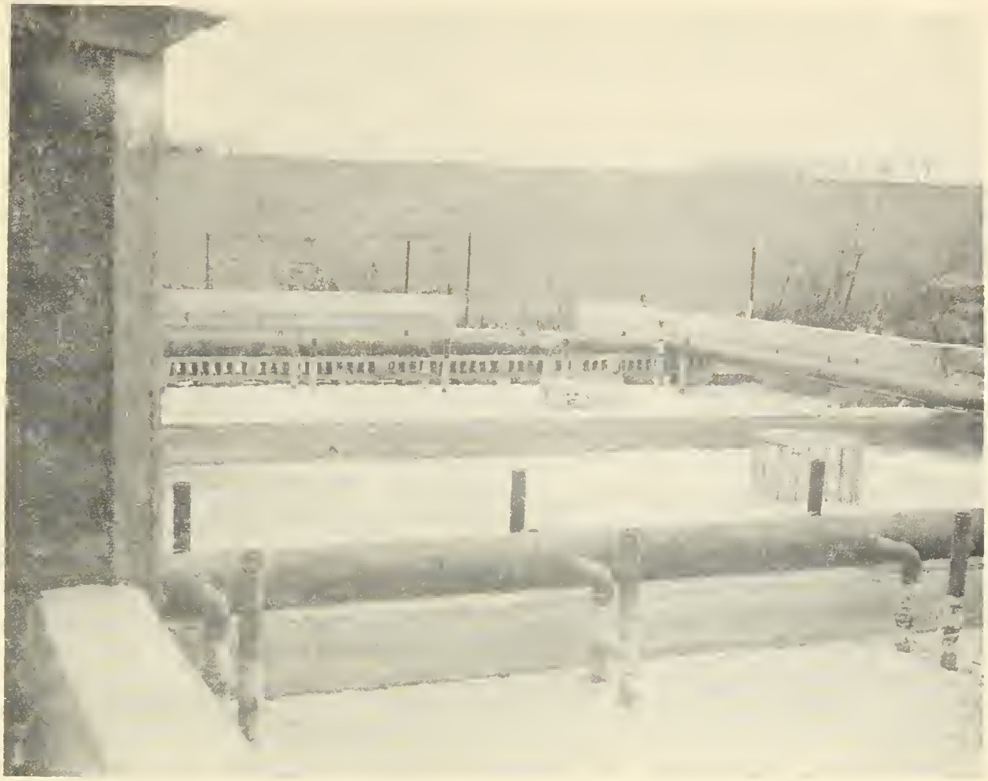

Figure 1
Jet-aeration of 25,000 gallons of waste; fill-and-draw method.

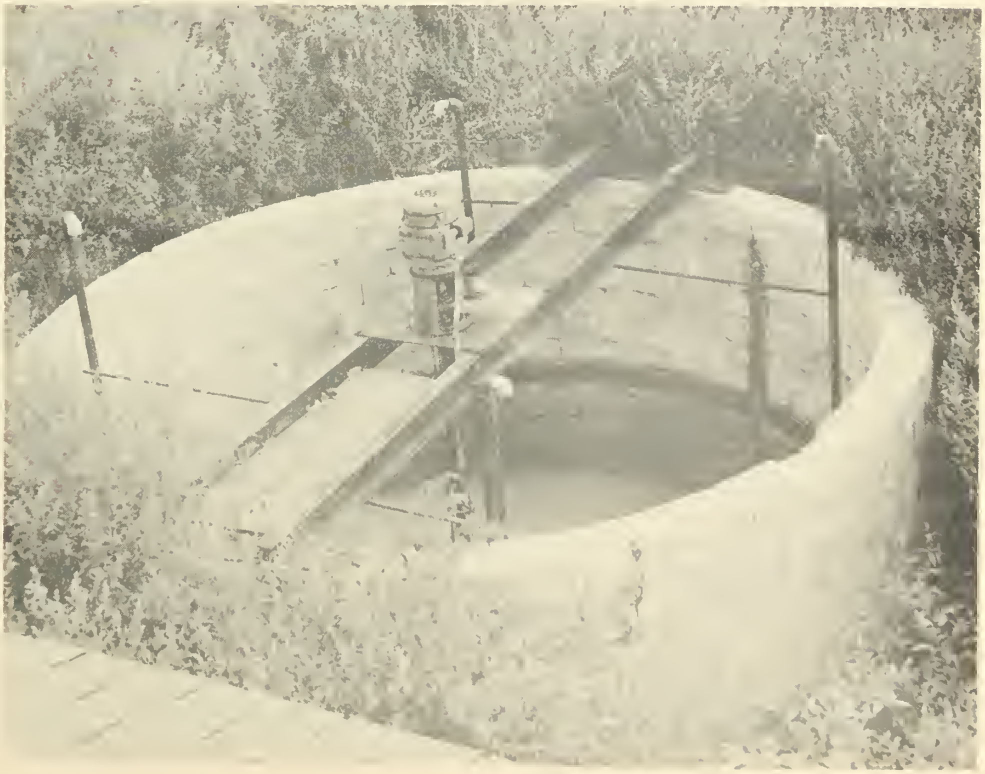

Figure 2
Four-jet aeration unit treating 6,000 gallons of waste; fill-and-draw method.

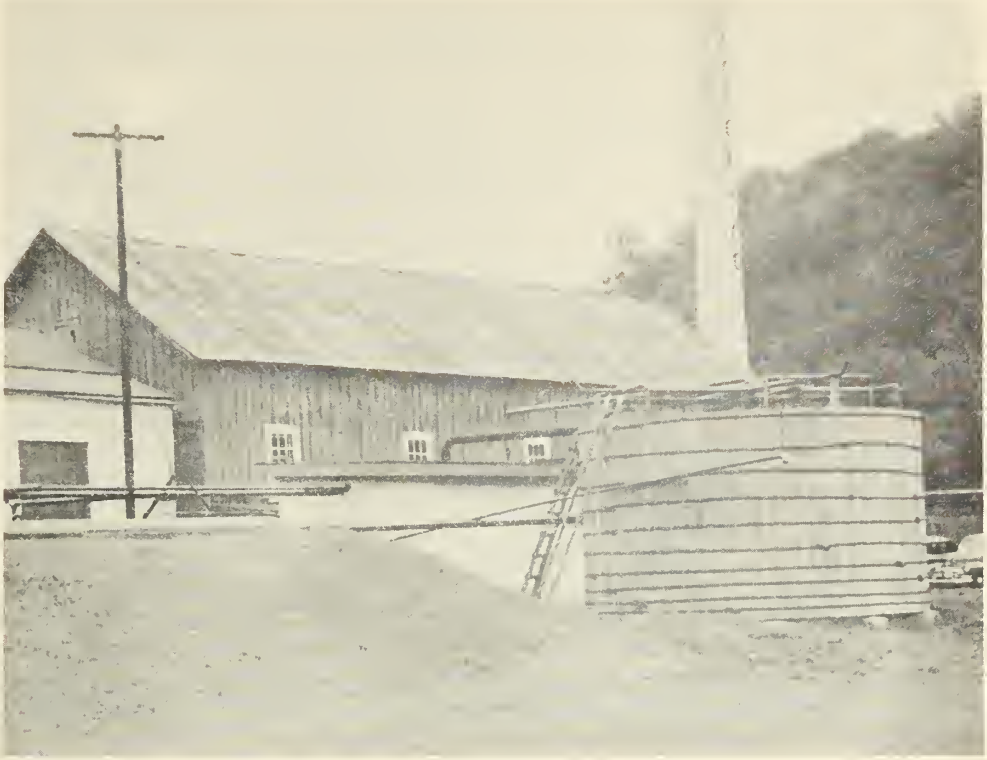

Figure 3
High-rate jet aeration under air pressure for continuous treatment of 22,000 gallons of waste.

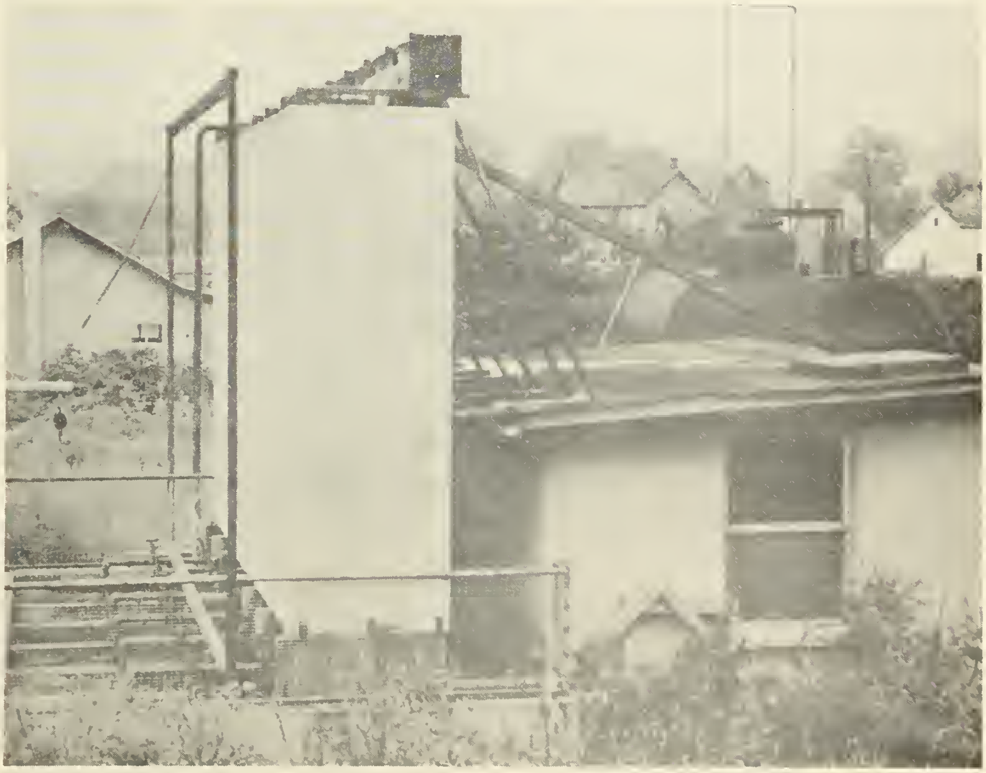

Figure 4
Combination jet and tower aeration for continuous treatment of 25,000 gallons of waste.